Progress in Polar Oceans Research Using ERS-1 Data

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ABSTRACT

Data from ERS- 1, especially from the AMI Image Mode, or SAR, have been particularly useful in providing data on ice type and motion and oceanic mesoscale features. These data have been used in studies of ocean and ice circulation, climate processes, mesoscale processes near the ice edge, freshwater fluxes, and convection, and have also proved useful in support of operations in ice covered seas,

INTRODUCTION

A major objective of the ERS-1 program has been to advance the science of the polar oceans through observations supporting modeling of sea ice and the adjacent open ocean. These data were also known to be useful in supporting shipping operations in ice-covered seas, and that aspect was pursued as an operational demonstrate ion.

All the instruments of ERS-1 are considered useful in sea ice and polar oceans observations, and the instrument of greatest applicability is the Advanced Microwave Instrument (AMI) in Image Mode in which the AMI functions as a Synthetic-Aperture Radar (SAR). The SAR is used in sea ice studies to describe the ice type present and to determine, through sequential observations, the ice motion field. These variables are seen to play significant parts in determining surface fluxes of heat, brine, and fresh water and thus to supply key information for studies in ocean circulation, convection, freshwater transport, and water mass alteration. Additionally, SAR data provides information on mesoscale features of the open sea, and this information has proved valuable in investigations of phenomena at the ice margin,

The AMI Wind Mode, or Scatterometer, data have been used in two ways, for the determination of the winds in the open water adjacent to the ice cover and to generate coarse-resolution maps of backscatter which are analyzed for large-scale temporal change. The ATSR instrument should prove valuable in supplying small-scale surface temperature data for the ice and adjacent ocean, but this analysis has only just begun. Finally, ERS-1 Altimeter data has been used to extend the information on ice type, and it will be used to better understand upper ocean dynamics when the polar geoid is better resolved and some Altimeter signal associated with the ice cover is properly accounted for.

Results summarized below are now in process of formal publication, but a number of them were presented in the ERS-1 Symposia of 1993 and 1994 (ESA, 1993; 1994)

ERS-1 RESULTS

ERS-1 investigators have had good success using the data from the SAR in ice studies. A number of important findings have resulted from these studies, with examples as follows:

The fundamental processes of ice opening and closing associated with large-scale deformation have been studied with the SAR (See Figure 1); this information is essential to understanding surface heat exchanges in ocean circulation studies, In past there have been numerous modeling assumptions as to the nature of the opening and closing under deformation; these assumptions included projections as to the yield curve and the granularity of the ice, but there have not been data sets to establish the actual behavior of the ice cover under wind and current forcing. ERS-1 supported results indicate that the yield behavior is intermediate between a circular curve and the consequences of pure divergence, in strong contrast to other recent results. More data are required in the regimes near pure compression and extension.

SAR derived ice motion fields have been used with buoy and wind analyses to construct ice circulation information for the entire Arctic Ocean; this is the only ocean for which the surface motion field is now known.

SAR images have also been used to identify ice types in the Bering, Beaufort, Chukchi, Barents, Greenland and Weddell Seas. The balance of ice types in these seas is expected to be a significant measure of seasonal Arctic climate and thus a sensitive signal of global warming Examination of temporal behavior of long strips of SAR data have been analyzed to map the seasonal advance of freezing and thawing in the Arctic Basin, and these trends are also considered to be sensitive to future global change.

Convective plumes in the Greenland Sea have been tentatively identified. These features, on a 300 m grid, occupy a zone of about 20X 90 km near the ice edge.

Ice melt processes in the Fram Strait area have been evaluated and compared with model results, and estimates have been derived for the flux of heat and brine across the Polar Front in that region.

The relationship between radar backscatter and ice thickness has been successfully compared to model predictions for regions in which the ice evolves with minimum disturbance, in leads and in some areas of the Southern Ocean.

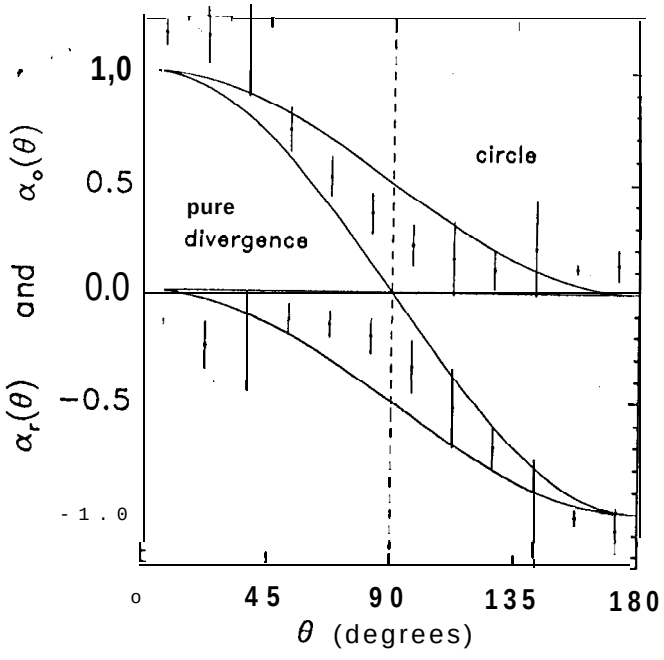
Ice motion in the Weddell Sea has been determined and shown to be consistent with wind forcing, and surface heat losses have been estimated (See Figure 2). This site is recognized to be an important site of deep convection, The large scale processes of the Weddell Sea have been successfully examined with the AMI Scatterometer mode, a novel application of the instrument motivated by the enormous scale of the ice cover and the limited SAR availability.

There are programs using the ATSR and Altimeter as well; the Altimeter is seen as an instrument useful for ice properties such as ridging intensity, and the ATSR should supply information on thin, warmer ice as well as the available heat in the waters of the ice margins; this heat plays a key role in the melting of ice and the consequent freshening of the surface waters of the sub-polar seas.

Operational support of shipping the Bay of Bothnia, the Northeast Passage, the Nansen Basin, the Chukchi Sea, and the Canadian Archipelago has successfully been provided by ERS-1 SAR through the various national ground stations. This program has been successful enough to prompt operational agencies to further plans with respect to SAR satellites later in the decade.

SUMMARY

In summary, sea ice studies supported by ERS- 1 data have evolved from the basic identification of ice types and ice motion fields into researches in both polar regions into the climatologically significant fluxes of heat, brine, and fresh water that drive the ocean and atmospheric circulation. Use of the data in operational support in ice-infested waters has also been established.



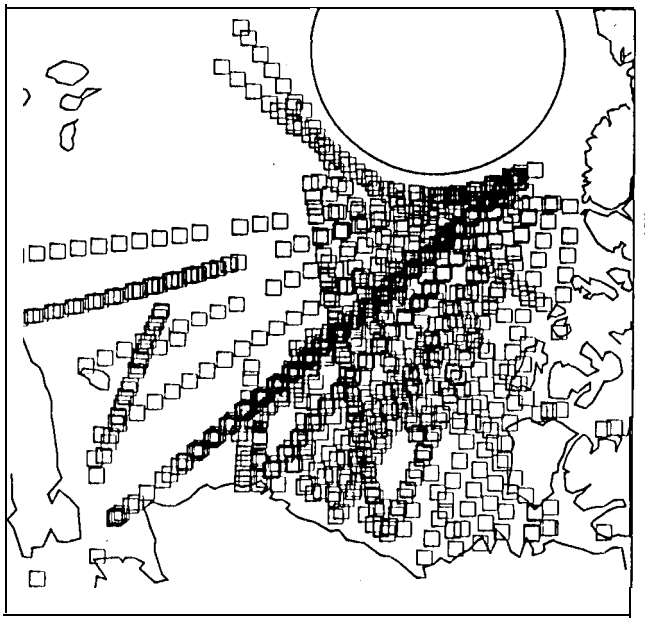


Figure 1.
Arctic Ocean Deformation Statistics

In the top figure opening and closing rates are shown as a function of the deformation angle (where uniaxial compression is 45° and extension is 1350), The outer solid lines show the expected behavior for a circular yield curve; the inner line is the expected behavior for pure divergence. In the lower curve are shown the sites of SAR data used m this analysis; the SAR data is processed into images which are then processed by the Alaska SAR Facility Geophysical Processor System to determine ice velocity and ice type. At that point the deformation and the production of opening and closing were estimated, (Courtesy of D. Rothrock)

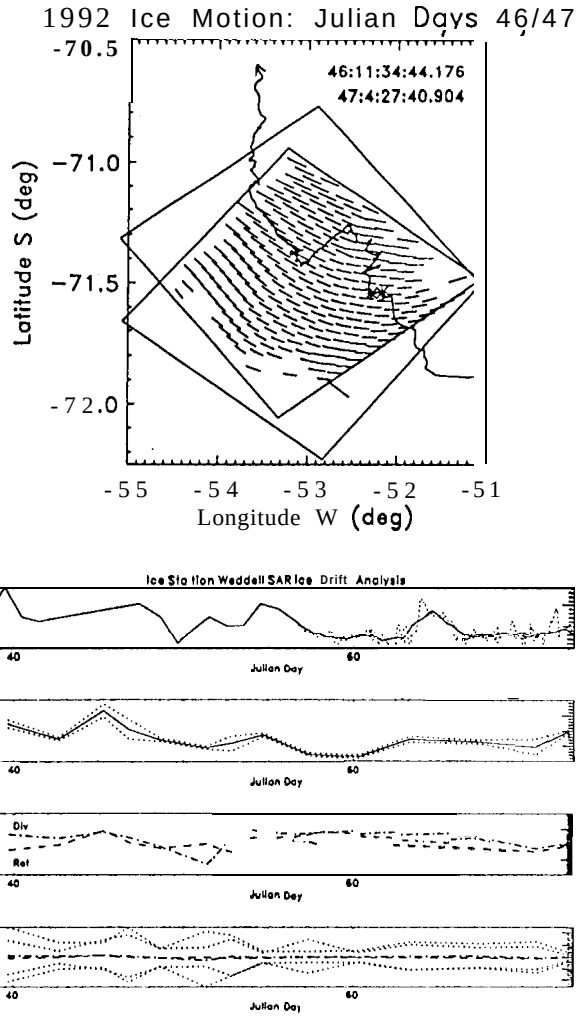


Figure 2
Weddell Sea Ice Dynamics

Ice dynamics in the Weddell Sea are shown. These results were derived from analysis of ERS- 1 SAR data from DPAF. In the upper figure the solid line is the ice translation as measured by drifting buoy, the rectangles are outlines of SAR frames; and the small lines are ice motion vectors derived from the SAR image pair, In the lower figures the wind derived from surface pressure is shown as is the ice speed, divergence, rotation, and their standard deviations, all derived from analysis of SAR images, (Courtesy of M. Drinkwater)

ACKNOWLEDGMENT

These research programs have relied on the ERS - 1 data stream which has proved to be capable of supplying impressive quantities of SAR (and other) data which are calibrated to about a 1 dB level, stable to better than that over time, reliably acquired, and efficiently provided to the research community,

REFERENCES

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